# PATENT ABSTRACTS OF JAPAN

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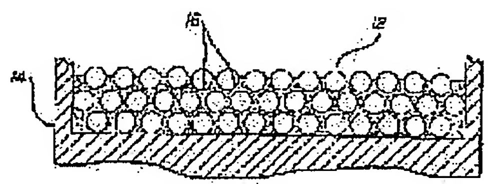
## (54) POT-SHAPED OPTICAL FIBER GYROSCOPIC SENSOR COIL

(57)Abstract:
PURPOSE: To provide a gyroscopic sensor coil for use in a severe vibratory and thermal environment by forming a coil in a pot shape from a silicon material containing a filler of carbon black, enhancing the hardness of polymer within the elasticity region, and decreasing the bias sensitivity of a gyroscope for vibrations.
CONSTITUTION: The winding of an optical fiber 12 is robotized within the base material consisting of adhesive 16. Generally, the existence of adhesive 16 provide many advantages because of gyroscopic effect, including the promotion of preciseness in the coil windings. That is, the adhesive 16 is turned in pot shape applied layer by layer and hardened, so that smooth surfaces are generated among the windings of the subsequent layers. Such windings encourage the control of the coil structure resulting therefrom including essential factors such as the fiber spacing, the number of turns per layer, and the number of layers per coil and minimizes the winding defects such as shortage of turns.

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## CLAIMS

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[Claim(s)]
[Claim 1] the sensor coil for optical fiber gyroscopes -- it is -- a optical fiber and b -- said fiber is prepared in the layer of two or more said alignment-cylindrical shapes -- having -- c -- from the turn of plurality [ each class / said ] of said fiber -- becoming -- d -- said the turn of each is prepared to the coil pattern decided beforehand -- having -- e -- the sensor coil characterized by to encapsulate said the turn of each with the pot-ized ingredient which has glass transition temperature outside the operating range of said gyroscope.
[Claim 2] It is the sensor coil characterized by said pot-ized ingredient containing silicon further in a sensor coil according to claim 1.
[Claim 3] It is the sensor coil characterized by including the bulking agent of a presentation with which said pot-ized ingredient was further decided beforehand in the sensor coil according to claim 2.
[Claim 4] It is the sensor coil said whose bulking agent is carbon black in a sensor coil according to claim 3.
[Claim 5] It is the sensor coil with which said bulking agent consists of a glass particle in a sensor coil according to claim 3.
[Claim 6] It is the sensor coil with which said bulking agent consists of silicon carbide in a sensor coil according to claim 3.
[Claim 7] It is the sensor coil with which said bulking agent consists of a graphite in a sensor coil according to claim 3.
[Claim 8] It is the sensor coil with which said bulking agent consists of fine particles of an aluminum oxide in a sensor coil according to claim 3.

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## DETAILED DESCRIPTION

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[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to an optical fiber gyroscope. Especially this invention relates to the pot-like sensor coil design used for an intense oscillating environment or the temperature environment where it changes rapidly.
[0002]
[Description of the Prior Art] The optical fiber gyroscope of an interferometer consists of the following main components. Namely, (1) light source, (2) the requirement of reciprocity gestalt" (S.Ezekiel and M.J.Arditty, Fiber Optic Rotation Sensors, New York, Springer-Verlag p.2-26 1982) of "min The beam splitter for being satisfied (the direction coupler of an optical fiber, and/or integrated optics Y branch), (3) They are the optical fiber detection coil made from either the polarization maintenance (PM) fiber or the low birefringence (standard telecommunication) fiber, (4) polariscopes (and the time one or more polarization disappearance machines), and (5) detectors. The light from the light source is divided into the wave which is transmitted in a detection coil and which is mutually spread to hard flow by the loop-formation beam splitter.

Related electronics measures the phase relation between two back propagation light beams which are generated from the both ends of a coil and in which it interferes. The difference of the phase shift experienced with two beams is proportional to the rotational speed of the bench where an instrument is fixed for the well-known Sagnac effect.

[0003] An environmental factor may affect the phase shift difference between the back propagation beams measured, and, thereby, may carry in a bias error. Said environmental factor contains temperature, vibration (an acoustical thing and mechanical thing), and a variate like a field. Generally, said factor changes with time amount, is not uniform to the everywhere of a coil and is distributed over it. These environmental factors cause change of the course of an optical light which encounters as each back propagation wave progresses the inside of a coil. The phase shift caused by said two waves produces equally the phase shift which distinction does not attach and which is not desirable as for net from a rotation calling-on signal.

[0004] One approach for decreasing the sensibility produced from an environmental factor needed use of various symmetry mold coil coil gestalten. In said coil, while the core on the structure of this coil is located in an innermost layer, a coil is prepared so that two edges of this coil may be located in the outermost layer. N FURIGO (N. Frigo) "Compensation of Linear Sources of Non-reciprocity in Signal Interferometers", Fiber Optics and Laser Sensors I, Prcs.SPIE, Vol.412, and p.268 (1983) It set and use of the specific coil pattern for compensating nonreciprocal nature was advocated. Furthermore, BEDONARUTSU entitled an "optical fiber detection coil" (Bednarz) U.S. Pat. No. 4,793,708 is teaching the symmetry mold optical fiber detection coil formed by two poles or 4 pole coil. The coil indicated by this patent shows the reinforced engine performance in which the conventional spiral type coil is excelled.

[0005] Ivancevic who entitles "4 Pole coil mold optical fiber detection coil and its manufacture approach" (Ivancevic) U.S. Pat. No. 4,856,900 is teaching improved 4 pole coil mold coil with which a fiber bundle and the minute crookedness resulting from existence of the pop-up fiber segment which adjoins an edge flange are conquered in said pop-up segment by replacing between connection layers with the turn wall which goes up, and which is rolled in the said alignment. Both the United States patents mentioned above are the ownership of the grantee in here. Although a suitable coil coil technique makes min a part of bias error during the output of an optical fiber gyroscope, it cannot lose all of said bias. Especially the design of a gyroscope sensor coil can have effect strong against a random pace of a gyroscope, bias stability, bias temperature sensitivity, bias temperature gradient sensibility, bias oscillating sensibility, bias oscillating sensibility, bias MAG sensibility, scale-factor temperature sensitivity, scale-factor linearity, and input-shaft temperature sensitivity.

[0006] Since the precision of a coil coil is promoted, it is accepted to be useful to pot-ize the coil of a sensor coil in the substrate of adhesives. Furthermore, the thing for which it can have considerable **** on the oscillating bias sensibility of an optical fiber gyroscope by the non-repulsion-phase shift between the light waves which spread the inside of a coil to hard flow mutually as a result of change of fiber length and a refractive index caused by oscillating dynamic distortion the presentation of a pot-ized ingredient Joint inventor AMADO entitled "the sensor coil for low bias optical fiber gyroscopes" Cordoba (Amado Cordova), Donald Jay Villin skiing (Donald J.Bilinski), Samuel N FERUSHUTO (Samuel N.Fersht), Grain Em surra BIAN (Glenn M.Surabian), John Di Wild (John D.Wilde) one And the pole Ray HIMMAN (Paul A.Hinman) -- pending in court -- it was indicated by the United States patent application 07th / No. 938,294. The quoted United States patent application is indicating the sensor coil including many descriptions that a design makes the above-mentioned environmental factor min. It is

checked in this patent application and the modulus of elasticity of a pot-ized ingredient presentation of a capsule-like sensor coil and the relation of oscillating induction bias in the point of argument currently tackled are.

[0007] Generally the gyroscope engine performance about oscillating induction bias a high modulus of elasticity (other problems relevant to the gyroscope actuation in the temperature which is fairly separated from the curing temperature of a pot-ized ingredient --), i.e., Young's modulus so that the coil crack relevant to temperature, h PAREMETA (polarization cross linking) degradation in case a coil consists of a PM fiber presentation, and big bias temperature sensitivity are produced -- not being high -- being sharply improved, if the pot-ized ingredient which it has is used is indicated by this application. A polymer is the attractive candidate of an adhesive pot-ized ingredient because of general properties like substantial impermeability, such as moisture. A sensor coil is assembled by the polymer which materializes instruction of the quoted patent application. For example, the coil encapsulated with UV hardening polyacrylate adhesive marketed with the trademark "NORLAND 65" showed sufficient oscillating bias property. However, when it circulated through a temperature requirement including the operating range of a gyroscope, said coil showed the transformation relevant to temperature shaken to some extent. These include so-called "bias spiking" and "bias crossing." The aforementioned phenomenon can bar good actuation of a gyroscope remarkably respectively. Since it becomes magnitude to the extent that a bias spike removes a gyroscope from a specification, bias crossing cannot occur, i.e., the capacity to express the bias error which is not practical may be shown effectively.

[0008]

[Means for Solving the Problem] This invention tackles the fault and fault of the above of the conventional technique, and an addition, and offers the sensor coil for optical fiber gyroscopes. Such a coil contains an optical fiber. This fiber is prepared by the layer of two or more said alignment-cylindrical shapes. Each class consists of two or more turns of a fiber, and each turn is prepared by the coil pattern decided beforehand. Said turn is encapsulated with the pot-ized ingredient which has glass transition temperature outside the operating range of a gyroscope. The above, other descriptions, and advantage of this invention will become still clearer from the following detailed explanation. The aforementioned explanation is accompanied by the drawing of a lot. The number of a drawing pointed out the various descriptions of this invention corresponding to the figure of an explanatory note, and the same figure has pointed out the same description also in any.

[0009]

[Example] When a drawing is referred to, drawing 1 is the perspective view of the sensor coil 10 by this invention. As mentioned above, the sensor coil 10 offers the important component of an optical fiber gyroscope system. The sensor coil 10 fixes to the bench where rotational speed should be measured at the time of use. The sensor coil 10 consists of an optical fiber 12 wound around the support spool 14, and serves as lightguide which receives the beam pair which is emitted from the common light source (not shown), and which is mutually spread to hard flow. Although the support spool 14 of drawing 1 contains an edge flange, the existence does not form a part of invention charged.

[0010] Spool 14 is Amoco Corp. (Amoco Corporation) suitably under the mixture of carbon mixture or a trademark "P-25", "P-55", or "P-105". Although marketed from supply [ like ] origin, it consists of other ingredients (hardening ingredient which has a low coefficient of thermal expansion especially) which have the same temperature-increase-by-plastic-working

property which contains a ** carbon fiber [ like ], and which is indicated by the United States patent application 07th under connection / No. 938,294. Spool 14 is formed with the fiber made by many fiber layer tubes or sheets by the junction substrate which consists for example, of a phenol ingredient. Spool 14 may be formed from said tube or sheet by many known approaches containing the cutting section from them. As a substitute, a ** fiber can be prepared in the direction decided beforehand, is made into a certain tint, and forms the mold of the cementing material which surround it. The chopped-up fiber is mixed by the migration molding material and the transfer molding transported or pressed fit in migration shuttering is used for other approaches. A fiber is suitably oriented with the right angle by which alignment was carried out to the direction of a major axis, and the circumferencial direction to the revolving shaft 22 of a spool within the junction substrate ingredient. By preparing a fiber such, spool 14 will expand symmetrically to the direction of a major axis, and radial according to temperature.

[0011] The theoretical model of the bias nonreciprocal nature of the optical fiber gyroscope clarified by the artificer is indicating that the gyro bias error in a dynamic heat environment may originate in thermal stress as indicated by the quoted patent application. This effectiveness It is the same as "Thermally Induced Non-Reciprocity in the Fiber Optic Interferometer", D.M.Shupe, Applied Optics, Vol.19, and the standard temperature Shupe effectiveness announced by p.654 (1980). The use of spool 14 based on carbon mixture tackles the thermal mismatching which exists between one of said the sources of bias, i.e., a glass optical fibre and the conventional metal spool. Other driving sources of thermal stress induction bias are the thermal stress by expansion/contraction of a coil pot-ized ingredient (it explains below). The difference between the standard temperature Shupe effectiveness and the Shupe effectiveness caused with thermal stress becomes remarkable clearly, when a coil is exposed to a stationary temperature gradient. The bias error by the standard Shupe effectiveness is lost as soon as a temperature gradient becomes fixed according to time amount, but the bias error by the thermal stress effectiveness does not become zero while the temperature of a coil is changing, but the effectiveness remains, until after a temperature gradient reaches a steady state. Although the standard Shupe effectiveness will mainly become the function of the rate of change of the temperature gradient which crosses a coil if such effectiveness is contrasted, the Shupe effectiveness caused with thermal stress mainly serves as a function of the rate of change of the mean temperature of a coil.

[0012] Drawing 2 is some [ typical ] expanded sectional views of the coil used as the layer of an optical fiber 12. The coil of an optical fiber 12 is pot-ized in the substrate which consists of adhesives 16 so that it may see in drawing. Generally, existence of said adhesives 16 offers many advantages for a gyroscope. These include promotion of the precision of a coil coil. That is, one layer of pot-ized adhesives 16 is applied at a time, it hardens, and a smooth front face can exist between the coils of a consecutive layer. Such a coil situation reinforces control of the coil structure produced as a result of [ the ] including an indispensable factor like fiber spacing, the number of turns per layer, and the number of layers per coil, and makes the minimum a coil defect like "lack of a turn."

[0013] In order for a turn, i.e., a coil, to make the coil embedded at the substrate of pot-ized adhesives, the various manufacture approaches can be used. Said approach includes spreading and hardening of adhesives for example, by the syringe mold dispenser. Said approach guarantees that a front face smooth for the coil of a consecutive image is offered. uv hardening adhesives which can be hardened quickly fit said approach most. Other manufacture approaches contain the dry type coil coil accompanied by the vacuum impregnation by very low viscous adhesives. The heat-curing adhesives applied while rolling a coil are used for other wet coil

techniques. These adhesives are twisted, and inside remains not hardening (with flow gestalt). Subsequently, the completed coil (wound) heat-hardens.

[0014] Although pot-ization of a coil offers many advantages, selection and the method of application of a pot-ized ingredient can affect the gyroscope engine performance fairly in itself. Especially, considerable reduction of the sensibility of the sensor coil 10 to an oscillating induction bias error and a temperature effect can be carried out by careful selection of the pot-ized adhesives 16. The bias oscillating sensibility of a sensor coil is produced from the operation in a coil into which a nonreciprocal nature phase error undistinguishable from a rotational-speed signal is introduced during the output. Said sensibility is caused by the non-repulsion-phase contrast of the wave mutually spread to hard flow produced from change of the fiber length and refractive index which subtract by oscillating dynamic distortion and are exceeded one by one. This bias error is similar with the Shupe bias error of the above-mentioned [ that property ], and the main differences are that an environmental disturbance becomes vibratility distortion from a temperature change rather.

[0015] When resonance frequency had separated from the artificer sharply from instrument engine-performance bandwidth, it observed experimentally that the open-loop response of the gyroscope to a sinusoidal oscillating sweep became the linear function of oscillation frequency (and when a noise factor can be disregarded). as for this, the oscillating direction becomes parallel to a coil input shaft -- **** (it is shaft-orientations vibration) -- or it is sure to that one which is perpendicular (it is longitudinal direction vibration) of cases. That is, the bias oscillating sensibility of an optical fiber gyroscope became the linear function of oscillation frequency, and the result predicted with the bias oscillating sensibility model was clarified by the artificer. Furthermore, under longitudinal direction vibration, the gyroscope output shows the azimuth (that is, it changes as SIN of whenever [ azimuth-angle ]) dependence of a sine wave mostly.

[0016] The result of this oscillating sensibility is serious. Even if the direct-current DC-bias effectiveness called "DC rectification" even if is not observed, the saturation caused by vibration of an electronic component can prevent closed loop electronics from the monitor of the rotational speed of fixed oscillation frequency. This may appear as DC rectification seemingly. Moreover, an angular-velocity noise arises not only from false cone formation of a system level but from said vibration. The problem relevant to an above-mentioned vibration can lose whether it is made min by preparing the substrate and fiber coil which consist of pot-ized adhesives so that the oscillating dynamic stress produced in a fiber coil may become min. The high stress and the distortion in a fiber core are produced by dynamic magnification. This harmful dynamic magnification effectiveness may be followed by use of the pot-ized adhesives which have the hardness of inadequate elasticity. however, it is restricted whether use of the very high pot-ized ingredient of Young's modulus is suppressed to some extent until according to the fixed temperature related effectiveness that a pot-ized ingredient becomes hard too much. H parameter (polarization cross linking) degradation in case a coil crack and a coil are the products made from PM fiber, and big bias temperature gradient sensibility are in such effectiveness. Sufficient solution to oscillating induction bias was found out by originating in the viscosity and a capsulation property, and pot-izing a sensor coil by greatly desirable various polymers. However, when the coil was pot-ized by the polymer, it turned out that a gyroscope shows other considerable bias errors which appear regardless of vibration. For an artificer, to the most important thing, the disturbance phenomenon of bias spiking and/or bias crossing is NORLAND. It found out being uniformly generated in the gyroscope using a coil pot-ized ingredient like UV hardening acrylic adhesives marketed as 65. Said transformation appears, when a sensor coil

circulates across an operational temperature range.
[0017] Drawing 3 is the graph of the relation of the coil (about -it continues for 10-degree-C thru/or 70 degrees C) temperature pair bias error (whenever [ per time amount ]) about the gyroscope containing the sensor coil pot-ized with NORLAND65 acrylic adhesives. A test coil is 200-meter Corning, Inc. (Corning corporation). It constituted from 165 micron fibers of make. It was wound around the mandril which consists of carbon composite material at the 20-layer gestalt. The inclination of the coil temperature was carried out to height. The data as what is plotted were amended about both a gyroscope output, the linear relation of temperature, and the rate dependence of temperature. The remaining residual bias is characterized with the standard deviation of 0.62 degrees per time amount as coil temperature circulates through for -10 degrees C and 70 degrees C. Sudden and extreme deviation (bias spike) of data is produced in per 50 degrees C so that it may see in drawing. The bias spike of drawing is over 5 times per time amount.
[0018] Drawing 4 is [ about ]. -It is NORLAND which circulated for 25 degrees C and 70 degrees C. It is the same graph of the data obtained from other sensor coils pot-ized by 65. The data from this coil express the bias crossing phenomenon. 0.61 was obtained with the peak two peak bias bias to which a standard deviation exceeds 4 times per time amount. The plot of the data obtained from the direction where temperature gradients differ crosses mutually by two corresponding to about 5 degrees C and 50 degrees C. Said crossing shows that the bias dependence (namely, Shupe multiplier) over the rate of a temperature change becomes in temperature dependence similarly. Said dependence is made very complicated to modeling of bias, and analysis of the bias which models the bias error besides the gyroscope output signal which is not practical one by one.
[0019] The artificer related the above-mentioned phenomenon with the physical operation of the polymer used as a pot-ized ingredient. Each polymer is characterized by the temperature requirement where the so-called considerable change of the glass transition region of that, i.e., the Young's modulus of an ingredient, is observed. The transition to the condition that there is elasticity from the condition of glassiness occurs as temperature increases this field. A polymer can show change of hardness from more than 150,000p.s.i. to 400p.s.i. over the glass transition region. Drawing 5 is temperature in case the temperature goes up to 100 degrees C from -100 degrees C, and hardened NORLND. It is the graph of the relation of the Young's modulus of 65. A sudden reduction of the Young's modulus of an ingredient started, when these acrylic adhesives got cold to about 0 degrees C, and said transition has finished with about 50 degrees C so that it may see in drawing. This supports the physical transition to the condition that there is elasticity from the condition of glassiness. The core of a transition region is mostly in agreement with the peak 18 of the graph of the dotted-line part of the Young's modulus which happens at 28 degrees C. NORLAND The Young's modulus of 65 changes to about 400p.[ from about 220,000p.s.i. ] s.i. over said transition region, and hardness decreases 500 times.
[0020] The artificer noted that the harmful phenomenon of bias spiking and bias crossing happened at the temperature of the inside of the glass transition region of this pot-ized ingredient, or near. The artificer actually found out that both "bias spiking" and "bias crossing" happened per 50 degrees C near the two "edges" of a transition region (i.e., per 0 degrees C). This reasoned correlation between whenever [ temperature dependence / of a bias phenomenon ], and a glass transition region operation of a polymer pot-ized ingredient, and it led the artificer so that it may make a new pot-ized ingredient based on it. the glass transition temperature which be outside the operating range of (1) gyroscope according to it in order that an artificer may decrease bias

oscillating sensibility effectively to acceptable level, and (2) (based on the oscillating resonance predict to be a coil configuration factor) -- it hunted for [ the pot-ized ingredient based on the polymer for sensor coils characterize with both quite big elastics modulus ].

[0021] Generally, although the commercial application is the specification of operating range (-40 degrees C thru/or 60 degrees C), a military specification requires the actuation covering a field (-55 degrees C thru/or 105 degrees C). Naturally, it is NORLAND. Making into a misfortune the harmful bias spike and the bias crossing as a result of [ of the sensor coil pot-ized by 65 ] glass transition temperature and as a result of, and being enough contained in both military and the operating-temperature specification for commerce attracts attention. An artificer is NORLAND about the coil and gyroscope which were pot-ized. The pot-ized ingredient based on a polymer which is not exposed to the error of the type experienced by the polymer of the 65th grade was developed. This was attained by two approaches. In the first place, the pot of the coil is carried out with the polymer adhesives which have a glass transition region outside the operational temperature range of a gyroscope sensor coil. Dependence of the oscillating induction bias to hardness is accepted [ second ], and in order to harden a polymer to a field with elasticity so that required Young's modulus may be obtained, suitable "bulking agent" can be added to a polymer.

[0022] Especially the artificer discovered the silicon which offers a good candidate ingredient. Those glass transition temperature exists out of specification [ -55 degrees C or less therefore commerce, and military ]. Therefore, although there is no something to say in guaranteeing that the aforementioned ingredient does not happen during gyroscope actuation usual in a considerable change of the Young's modulus of the ingredient which results in a bias spike or bias crossing, the Young's modulus of said ingredient in the temperature field exceeding a glass transition region (it is forward much more than it) has a rate fairly lower than below a transition region. Naturally this is the symptom of all polymers. For example, in drawing 5 , although it is the place of the hardness to which transition temperature cannot become so large that the desirable resistance to oscillating induction bias is given and which carried out considerable reduction, when a limit is exceeded, it can note that Young's modulus becomes stability very much. Similarly, the Young's modulus of a silicon ingredient is only abbreviation 370p.s.i., therefore drawing 6 A shows that it is not so hard as required because of the gyroscope required of operating in a severe oscillating environment.

[0023] The artificer found out that some "bulking agents" which consist of a changing ingredient presentation could be added to silicon, and the ingredient engine performance about oscillating induction bias could be reinforced. therefore, the time of glass transition temperature exceeding a limit, as for addition of said bulking agent -- a silicon ingredient -- " -- only -- the comparatively low Young's modulus of "-- ******** -- it makes it possible to obtain desirable oscillating resistance. In short, addition of a bulking agent makes the hardness of silicon increase to a field with elasticity, and decreases gyroscope oscillating sensibility on desirable level. Carbon black is in the bulking agent which makes the pot-like sensor coil which has an excellent bias property. It is known that this ingredient will react to rubber and a chemistry target so that tensile strength and Young's modulus may increase. Therefore, carbon black is known as a reinforcing filler of rubber. The artificer found out that the reinforcement property of carbon black was applicable to above-mentioned various problems. Moreover, the coil pot-ized with the silicon which carbon black makes increase the condensation reinforcement of a silicon presentation, consequently contains a carbon black bulking agent can bear further the crack caused thermally and the delamination by condensation fall. When various bulking agents are added by only silicon, it

must mind about the possibility of adhesion or degradation of bonding strength. "Baking" of a fiber 75 degrees C or more raises the bonding strength of a fiber and a pot-ized ingredient. Other satisfactory bulking agents for the silicon pot-ized ingredient which is not contained by the artificer contain a glass particle, Xtal, silicon carbide, a graphite, and alumina (aluminum oxide) powder.

[0024] Drawing 6 A is a master bond shrine (Master Bond, Inc.) of New Jersey and Hackensack (Hackensack) marketed with the trademark "Mastersyl 151". It is the graph of the temperature pair Young's modulus about a silicon presentation. Drawing 6 B is the graph of the temperature pair Young's modulus of the same silicon ingredient with which it filled up with carbon black. The used carbon black bulking agent is the Canada country and Alberta (Alberta). A state, Mehdi Soon Can curve company of a hat (Medicine Hat) (Cancarb Limited) It was THERMAX Medium Thermal Black N -991 marketed. Glass transition of a silicon ingredient has placed the core per -66 degrees C that the hardness of an ingredient decreases detrimentally as temperature increases to about 370p.s.i. more than glass transition temperature so that drawing 6 A may see. A glass transition region is still nicer and this operation should be contrasted with the silicon ingredient with which it filled up with the carbon black of drawing 6 B which puts a core on -72 degrees C below gyroscope operating range. Since a bulking agent is heated more than glass transition temperature, that the Young's modulus of an ingredient is seen decreasing gradually arises. If it contrasts with the silicon ingredient lacking in a bulking agent, by the way, the sample of drawing 6 B is approaching the stable Young's modulus of the value of abbreviation 1,500p.s.i. in a field with elasticity. Thus, experimental data has proved the specific bulking agent, i.e., the effectiveness of carbon black, as what hardens a silicon ingredient when heated more than the glass transition temperature.

[0025] The artificer applied the desirable property of the observed silicon and a silicon restoration pot-ized ingredient to manufacture of a gyroscope sensor coil, and realized the remarkable result about the engine performance which improved. Drawing 7 is the graph of a bias error as a function of temperature about the gyroscope containing the sensor coil pot-ized by the silicon presentation hardened by the carbon black of drawing 6 B. Bias data were obtained from 40 layer-winding sensor coil formed with the 200-meter 165-micron optical fiber by Corning, Inc. The data of drawing 7 are amended about both a gyroscope output and the linear relation of temperature, and the rate dependence of temperature like [ in the case of the data plotted by drawing 3 and the graph of 4 ]. Becoming what has the standard deviation of 0.19 degrees per time amount, and the residual bias which remains can disregard as the temperature of a sensor coil circulates through for -50 degrees C and 95 degrees C is seen. Neither a bias spike nor bias crossing exists in the data of drawing 7 . If the data of drawing 7 , drawing 3 , and the data of 4 are contrasted, it will be dramatic and an artificer's penetration and assumption will be proved about the property of the problem relevant to pot-izing a sensor coil by the polymer.

[0026] Drawing 8 is the graph of AC bias by oscillation frequency pair sine wave vibration about the coil pot-ized with the silicon with which it filled up with carbon black. This bias data was similarly obtained from 40 layer-winding coil formed with the 200-meter 165-micron optical fiber by Corning, Inc. AC bias output can be substantially disregarded in this measurand as this graph shows. The vibration acceleration level was kept constant at 1g. Thus, it turns out that instruction of this invention offers the sensor coil substantially improved about minimization of the bias sensibility resulting from dynamic heat and an oscillating environment. By using instruction of this invention, the gyroscope engine performance which is not substantially exposed to the bias error of the environmental cause that recognition or a measure was not made

before can be obtained with the conventional technique. Although this invention was explained about operation zero suitable at present, it does not restrict to it. Rather, this invention is restricted only in the limitation defined by the attendant claim, and contains all the equivalents of it within the limits of it.

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TECHNICAL FIELD

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[Industrial Application] This invention relates to an optical fiber gyroscope. Especially this invention relates to the pot-like sensor coil design used for an intense oscillating environment or the temperature environment where it changes rapidly.

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TECHNICAL PROBLEM

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[Description of the Prior Art] The optical fiber gyroscope of an interferometer consists of the following main components. Namely, (1) light source, (2) the requirement of reciprocity gestalt" (S.Ezekiel and M.J.Arditty, Fiber Optic Rotation Sensors, New York, Springer-Verlag p.2-26 1982) of "min The beam splitter for being satisfied (the direction coupler of an optical fiber, and/or integrated optics Y branch), (3) They are the optical fiber detection coil made from either the polarization maintenance (PM) fiber or the low birefringence (standard telecommunication) fiber, (4) polariscopes (and the time one or more polarization disappearance machines), and (5) detectors. The light from the light source is divided into the wave which is transmitted in a detection coil and which is mutually spread to hard flow by the loop-formation beam splitter. Related electronics measures the phase relation between two back propagation light beams which are generated from the both ends of a coil and in which it interferes. The difference of the phase shift experienced with two beams is proportional to the rotational speed of the bench where an instrument is fixed for the well-known Sagnac effect.
[0003] An environmental factor may affect the phase shift difference between the back propagation beams measured, and, thereby, may carry in a bias error. Said environmental factor contains temperature, vibration (an acoustical thing and mechanical thing), and a variate like a field. Generally, said factor changes with time amount, is not uniform to the everywhere of a coil and is distributed over it. These environmental factors cause change of the course of an optical light which encounters as each back propagation wave progresses the inside of a coil. The phase shift caused by said two waves produces equally the phase shift which distinction does not attach and which is not desirable as for net from a rotation calling-on signal.
[0004] One approach for decreasing the sensibility produced from an environmental factor needed use of various symmetry mold coil coil gestalten. In said coil, while the core on the structure of this coil is located in an innermost layer, a coil is prepared so that two edges of this coil may be located in the outermost layer. N FURIGO (N. Frigo) "Compensation of Linear Sources of Non-reciprocity in Signal Interferometers", Fiber Optics and Laser Sensors I, Prcs.SPIE, Vol.412, and p.268 (1983) It set and use of the specific coil pattern for compensating nonreciprocal nature was advocated. Furthermore, BEDONARUTSU entitled an "optical fiber detection coil" (Bednarz) U.S. Pat. No. 4,793,708 is teaching the symmetry mold optical fiber detection coil formed by two poles or 4 pole coil. The coil indicated by this patent shows the reinforced engine performance in which the conventional spiral type coil is excelled.
[0005] Ivancevic who entitles "4 Pole coil mold optical fiber detection coil and its manufacture

approach" (Ivancevic) U.S. Pat. No. 4,856,900 is teaching improved 4 pole coil mold coil with which a fiber bundle and the minute crookedness resulting from existence of the pop-up fiber segment which adjoins an edge flange are conquered in said pop-up segment by replacing between connection layers with the turn wall which goes up, and which is rolled in the said alignment. Both the United States patents mentioned above are the ownership of the grantee in here. Although a suitable coil coil technique makes min a part of bias error during the output of an optical fiber gyroscope, it cannot lose all of said bias. Especially the design of a gyroscope sensor coil can have effect strong against a random pace of a gyroscope, bias stability, bias temperature sensitivity, bias temperature gradient sensibility, bias oscillating sensibility, bias oscillating sensibility, bias MAG sensibility, scale-factor temperature sensitivity, scale-factor linearity, and input-shaft temperature sensitivity.

[0006] Since the precision of a coil coil is promoted, it is accepted to be useful to pot-ize the coil of a sensor coil in the substrate of adhesives. Furthermore, the thing for which it can have considerable **** on the oscillating bias sensibility of an optical fiber gyroscope by the non-repulsion-phase shift between the light waves which spread the inside of a coil to hard flow mutually as a result of change of fiber length and a refractive index caused by oscillating dynamic distortion the presentation of a pot-ized ingredient Joint inventor AMADO entitled "the sensor coil for low bias optical fiber gyroscopes" Cordoba (Amado Cordova), Donald Jay Villin skiing (Donald J.Bilinski), Samuel N FERUSHUTO (Samuel N.Fersht), Grain Em surra BIAN (Glenn M.Surabian), John Di Wild (John D.Wilde) one And the pole Ray HIMMAN (Paul A.Hinman) -- pending in court -- it was indicated by the United States patent application 07th / No. 938,294. The quoted United States patent application is indicating the sensor coil including many descriptions that a design makes the above-mentioned environmental factor min. It is checked in this patent application and the modulus of elasticity of a pot-ized ingredient presentation of a capsule-like sensor coil and the relation of oscillating induction bias in the point of argument currently tackled are.

[0007] Generally the gyroscope engine performance about oscillating induction bias a high modulus of elasticity (other problems relevant to the gyroscope actuation in the temperature which is fairly separated from the curing temperature of a pot-ized ingredient --), i.e., Young's modulus so that the coil crack relevant to temperature, h PAREMETA (polarization cross linking) degradation in case a coil consists of a PM fiber presentation, and big bias temperature sensitivity are produced -- not being high -- being sharply improved, if the pot-ized ingredient which it has is used is indicated by this application. A polymer is the attractive candidate of an adhesive pot-ized ingredient because of general properties like substantial impermeability, such as moisture. A sensor coil is assembled by the polymer which materializes instruction of the quoted patent application. For example, the coil encapsulated with UV hardening polyacrylate adhesive marketed with the trademark "NORLAND 65" showed sufficient oscillating bias property. However, when it circulated through a temperature requirement including the operating range of a gyroscope, said coil showed the transformation relevant to temperature shaken to some extent. These include so-called "bias spiking" and "bias crossing." The aforementioned phenomenon can bar good actuation of a gyroscope remarkably respectively. Since it becomes magnitude to the extent that a bias spike removes a gyroscope from a specification, bias crossing cannot occur, i.e., the capacity to express the bias error which is not practical may be shown effectively.

## MEANS

[Means for Solving the Problem] This invention tackles the fault and fault of the above of the conventional technique, and an addition, and offers the sensor coil for optical fiber gyroscopes. Such a coil contains an optical fiber. This fiber is prepared by the layer of two or more said alignment-cylindrical shapes. Each class consists of two or more turns of a fiber, and each turn is prepared by the coil pattern decided beforehand. Said turn is encapsulated with the pot-ized ingredient which has glass transition temperature outside the operating range of a gyroscope. The above, other descriptions, and advantage of this invention will become still clearer from the following detailed explanation. The aforementioned explanation is accompanied by the drawing of a lot. The number of a drawing pointed out the various descriptions of this invention corresponding to the figure of an explanatory note, and the same figure has pointed out the same description also in any.



## EXAMPLE

[Example] When a drawing is referred to, drawing 1 is the perspective view of the sensor coil 10 by this invention. As mentioned above, the sensor coil 10 offers the important component of an optical fiber gyroscope system. The sensor coil 10 fixes to the bench where rotational speed should be measured at the time of use. The sensor coil 10 consists of an optical fiber 12 wound around the support spool 14, and serves as lightguide which receives the beam pair which is emitted from the common light source (not shown), and which is mutually spread to hard flow. Although the support spool 14 of drawing 1 contains an edge flange, the existence does not form a part of invention charged.

[0010] Spool 14 is Amoco Corp. (Amoco Corporation) suitably under the mixture of carbon mixture or a trademark "P-25", "P-55", or "P-105". Although marketed from supply [ like ] origin, it consists of other ingredients (hardening ingredient which has a low coefficient of thermal expansion especially) which have the same temperature-increase-by-plastic-working property which contains a ** carbon fiber [ like ], and which is indicated by the United States patent application 07th under connection / No. 938,294. Spool 14 is formed with the fiber made by many fiber layer tubes or sheets by the junction substrate which consists for example, of a phenol ingredient. Spool 14 may be formed from said tube or sheet by many known approaches containing the cutting section from them. As a substitute, a ** fiber can be prepared in the direction decided beforehand, is made into a certain tint, and forms the mold of the cementing material which surround it. The chopped-up fiber is mixed by the migration molding material

and the transfer molding transported or pressed fit in migration shuttering is used for other approaches. A fiber is suitably oriented with the right angle by which alignment was carried out to the direction of a major axis, and the circumferencial direction to the revolving shaft 22 of a spool within the junction substrate ingredient. By preparing a fiber such, spool 14 will expand symmetrically to the direction of a major axis, and radial according to temperature.

[0011] The theoretical model of the bias nonreciprocal nature of the optical fiber gyroscope clarified by the artificer is indicating that the gyro bias error in a dynamic heat environment may originate in thermal stress as indicated by the quoted patent application. This effectiveness It is the same as "Thermally Induced Non-Reciprocity in the Fiber Optic Interferometer", D.M.Shupe, Applied Optics, Vol.19, and the standard temperature Shupe effectiveness announced by p.654 (1980). The use of spool 14 based on carbon mixture tackles the thermal mismatching which exists between one of said the sources of bias, i.e., a glass optical fibre and the conventional metal spool. Other driving sources of thermal stress induction bias are the thermal stress by expansion/contraction of a coil pot-ized ingredient (it explains below). The difference between the standard temperature Shupe effectiveness and the Shupe effectiveness caused with thermal stress becomes remarkable clearly, when a coil is exposed to a stationary temperature gradient. The bias error by the standard Shupe effectiveness is lost as soon as a temperature gradient becomes fixed according to time amount, but the bias error by the thermal stress effectiveness does not become zero while the temperature of a coil is changing, but the effectiveness remains, until after a temperature gradient reaches a steady state. Although the standard Shupe effectiveness will mainly become the function of the rate of change of the temperature gradient which crosses a coil if such effectiveness is contrasted, the Shupe effectiveness caused with thermal stress mainly serves as a function of the rate of change of the mean temperature of a coil.

[0012] Drawing 2 is some [ typical ] expanded sectional views of the coil used as the layer of an optical fiber 12. The coil of an optical fiber 12 is pot-ized in the substrate which consists of adhesives 16 so that it may see in drawing. Generally, existence of said adhesives 16 offers many advantages for a gyroscope. These include promotion of the precision of a coil coil. That is, one layer of pot-ized adhesives 16 is applied at a time, it hardens, and a smooth front face can exist between the coils of a consecutive layer. Such a coil situation reinforces control of the coil structure produced as a result of [ the ] including an indispensable factor like fiber spacing, the number of turns per layer, and the number of layers per coil, and makes the minimum a coil defect like "lack of a turn."

[0013] In order for a turn, i.e., a coil, to make the coil embedded at the substrate of pot-ized adhesives, the various manufacture approaches can be used. Said approach includes spreading and hardening of adhesives for example, by the syringe mold dispenser. Said approach guarantees that a front face smooth for the coil of a consecutive image is offered. uv hardening adhesives which can be hardened quickly fit said approach most. Other manufacture approaches contain the dry type coil coil accompanied by the vacuum impregnation by very low viscous adhesives. The heat-curing adhesives applied while rolling a coil are used for other wet coil techniques. These adhesives are twisted, and inside remains not hardening (with flow gestalt). Subsequently, the completed coil (wound) heat-hardens.

[0014] Although pot-ization of a coil offers many advantages, selection and the method of application of a pot-ized ingredient can affect the gyroscope engine performance fairly in itself. Especially, considerable reduction of the sensibility of the sensor coil 10 to an oscillating induction bias error and a temperature effect can be carried out by careful selection of the pot-ized adhesives 16. The bias oscillating sensibility of a sensor coil is produced from the operation

in a coil into which a nonreciprocal nature phase error undistinguishable from a rotational-speed signal is introduced during the output. Said sensibility is caused by the non-repulsion-phase contrast of the wave mutually spread to hard flow produced from change of the fiber length and refractive index which subtract by oscillating dynamic distortion and are exceeded one by one. This bias error is similar with the Shupe bias error of the above-mentioned [ that property ], and the main differences are that an environmental disturbance becomes vibratility distortion from a temperature change rather.

[0015] When resonance frequency had separated from the artificer sharply from instrument engine-performance bandwidth, it observed experimentally that the open-loop response of the gyroscope to a sinusoidal oscillating sweep became the linear function of oscillation frequency (and when a noise factor can be disregarded). as for this, the oscillating direction becomes parallel to a coil input shaft -- **** (it is shaft-orientations vibration) -- or it is sure to that one which is perpendicular (it is longitudinal direction vibration) of cases. That is, the bias oscillating sensibility of an optical fiber gyroscope became the linear function of oscillation frequency, and the result predicted with the bias oscillating sensibility model was clarified by the artificer. Furthermore, under longitudinal direction vibration, the gyroscope output shows the azimuth (that is, it changes as SIN of whenever [ azimuth-angle ]) dependence of a sine wave mostly.

[0016] The result of this oscillating sensibility is serious. Even if the direct-current DC-bias effectiveness called "DC rectification" even if is not observed, the saturation caused by vibration of an electronic component can prevent closed loop electronics from the monitor of the rotational speed of fixed oscillation frequency. This may appear as DC rectification seemingly. Moreover, an angular-velocity noise arises not only from false cone formation of a system level but from said vibration. The problem relevant to an above-mentioned vibration can lose whether it is made min by preparing the substrate and fiber coil which consist of pot-ized adhesives so that the oscillating dynamic stress produced in a fiber coil may become min. The high stress and the distortion in a fiber core are produced by dynamic magnification. This harmful dynamic magnification effectiveness may be followed by use of the pot-ized adhesives which have the hardness of inadequate elasticity. however, it is restricted whether use of the very high pot-ized ingredient of Young's modulus is suppressed to some extent until according to the fixed temperature related effectiveness that a pot-ized ingredient becomes hard too much. H parameter (polarization cross linking) degradation in case a coil crack and a coil are the products made from PM fiber, and big bias temperature gradient sensibility are in such effectiveness. Sufficient solution to oscillating induction bias was found out by originating in the viscosity and a capsulation property, and pot-izing a sensor coil by greatly desirable various polymers. However, when the coil was pot-ized by the polymer, it turned out that a gyroscope shows other considerable bias errors which appear regardless of vibration. For an artificer, to the most important thing, the disturbance phenomenon of bias spiking and/or bias crossing is NORLAND. It found out being uniformly generated in the gyroscope using a coil pot-ized ingredient like UV hardening acrylic adhesives marketed as 65. Said transformation appears, when a sensor coil circulates across an operational temperature range.

[0017] Drawing 3 is the graph of the relation of the coil (about -it continues for 10-degree-C thru/or 70 degrees C) temperature pair bias error (whenever [ per time amount ]) about the gyroscope containing the sensor coil pot-ized with NORLAND65 acrylic adhesives. A test coil is 200-meter Corning, Inc. (Corning corporation). It constituted from 165 micron fibers of make. It was wound around the mandril which consists of carbon composite material at the 20-layer gestalt. The inclination of the coil temperature was carried out to height. The data as what is

plotted were amended about both a gyroscope output, the linear relation of temperature, and the rate dependence of temperature. The remaining residual bias is characterized with the standard deviation of 0.62 degrees per time amount as coil temperature circulates through for -10 degrees C and 70 degrees C. Sudden and extreme deviation (bias spike) of data is produced in per 50 degrees C so that it may see in drawing. The bias spike of drawing is over 5 times per time amount.

[0018] Drawing 4 is [ about ]. -It is NORLAND which circulated for 25 degrees C and 70 degrees C. It is the same graph of the data obtained from other sensor coils pot-ized by 65. The data from this coil express the bias crossing phenomenon. 0.61 was obtained with the peak two peak bias bias to which a standard deviation exceeds 4 times per time amount. The plot of the data obtained from the direction where temperature gradients differ crosses mutually by two corresponding to about 5 degrees C and 50 degrees C. Said crossing shows that the bias dependence (namely, Shupe multiplier) over the rate of a temperature change becomes in temperature dependence similarly. Said dependence is made very complicated to modeling of bias, and analysis of the bias which models the bias error besides the gyroscope output signal which is not practical one by one.

[0019] The artificer related the above-mentioned phenomenon with the physical operation of the polymer used as a pot-ized ingredient. Each polymer is characterized by the temperature requirement where the so-called considerable change of the glass transition region of that, i.e., the Young's modulus of an ingredient, is observed. The transition to the condition that there is elasticity from the condition of glassiness occurs as temperature increases this field. A polymer can show change of hardness from more than 150,000p.s.i. to 400p.s.i. over the glass transition region. Drawing 5 is temperature in case the temperature goes up to 100 degrees C from -100 degrees C, and hardened NORLND. It is the graph of the relation of the Young's modulus of 65. A sudden reduction of the Young's modulus of an ingredient started, when these acrylic adhesives got cold to about 0 degrees C, and said transition has finished with about 50 degrees C so that it may see in drawing. This supports the physical transition to the condition that there is elasticity from the condition of glassiness. The core of a transition region is mostly in agreement with the peak 18 of the graph of the dotted-line part of the Young's modulus which happens at 28 degrees C. NORLAND The Young's modulus of 65 changes to about 400p.[ from about 220,000p.s.i. ] s.i. over said transition region, and hardness decreases 500 times.

[0020] The artificer noted that the harmful phenomenon of bias spiking and bias crossing happened at the temperature of the inside of the glass transition region of this pot-ized ingredient, or near. The artificer actually found out that both "bias spiking" and "bias crossing" happened per 50 degrees C near the two "edges" of a transition region (i.e., per 0 degrees C). This reasoned correlation between whenever [ temperature dependence / of a bias phenomenon ], and a glass transition region operation of a polymer pot-ized ingredient, and it led the artificer so that it may make a new pot-ized ingredient based on it. the glass transition temperature which be outside the operating range of (1) gyroscope according to it in order that an artificer may decrease bias oscillating sensibility effectively to acceptable level, and (2) (based on the oscillating resonance predict to be a coil configuration factor) -- it hunted for [ the pot-ized ingredient based on the polymer for sensor coils characterize with both quite big elastics modulus ].

[0021] Generally, although the commercial application is the specification of operating range (-40 degrees C thru/or 60 degrees C), a military specification requires the actuation covering a field (-55 degrees C thru/or 105 degrees C). Naturally, it is NORLAND. Making into a misfortune the harmful bias spike and the bias crossing as a result of [ of the sensor coil pot-ized

by 65 ] glass transition temperature and as a result of, and being enough contained in both military and the operating-temperature specification for commerce attracts attention. An artificer is NORLAND about the coil and gyroscope which were pot-ized. The pot-ized ingredient based on a polymer which is not exposed to the error of the type experienced by the polymer of the 65th grade was developed. This was attained by two approaches. In the first place, the pot of the coil is carried out with the polymer adhesives which have a glass transition region outside the operational temperature range of a gyroscope sensor coil. Dependence of the oscillating induction bias to hardness is accepted [ second ], and in order to harden a polymer to a field with elasticity so that required Young's modulus may be obtained, suitable "bulking agent" can be added to a polymer.

[0022] Especially the artificer discovered the silicon which offers a good candidate ingredient. Those glass transition temperature exists out of specification [ -55 degrees C or less therefore commerce, and military ]. Therefore, although there is no something to say in guaranteeing that the aforementioned ingredient does not happen during gyroscope actuation usual in a considerable change of the Young's modulus of the ingredient which results in a bias spike or bias crossing, the Young's modulus of said ingredient in the temperature field exceeding a glass transition region (it is forward much more than it) has a rate fairly lower than below a transition region. Naturally this is the symptom of all polymers. For example, in drawing 5 , although it is the place of the hardness to which transition temperature cannot become so large that the desirable resistance to oscillating induction bias is given and which carried out considerable reduction, when a limit is exceeded, it can note that Young's modulus becomes stability very much. Similarly, the Young's modulus of a silicon ingredient is only abbreviation 370p.s.i., therefore drawing 6 A shows that it is not so hard as required because of the gyroscope required of operating in a severe oscillating environment.

[0023] The artificer found out that some "bulking agents" which consist of a changing ingredient presentation could be added to silicon, and the ingredient engine performance about oscillating induction bias could be reinforced. therefore, the time of glass transition temperature exceeding a limit, as for addition of said bulking agent -- a silicon ingredient -- " -- only -- the comparatively low Young's modulus of "-- ******** -- it makes it possible to obtain desirable oscillating resistance. In short, addition of a bulking agent makes the hardness of silicon increase to a field with elasticity, and decreases gyroscope oscillating sensibility on desirable level. Carbon black is in the bulking agent which makes the pot-like sensor coil which has an excellent bias property. It is known that this ingredient will react to rubber and a chemistry target so that tensile strength and Young's modulus may increase. Therefore, carbon black is known as a reinforcing filler of rubber. The artificer found out that the reinforcement property of carbon black was applicable to above-mentioned various problems. Moreover, the coil pot-ized with the silicon which carbon black makes increase the condensation reinforcement of a silicon presentation, consequently contains a carbon black bulking agent can bear further the crack caused thermally and the delamination by condensation fall. When various bulking agents are added by only silicon, it must mind about the possibility of adhesion or degradation of bonding strength. "Baking" of a fiber 75 degrees C or more raises the bonding strength of a fiber and a pot-ized ingredient. Other satisfactory bulking agents for the silicon pot-ized ingredient which is not contained by the artificer contain a glass particle, Xtal, silicon carbide, a graphite, and alumina (aluminum oxide) powder.

[0024] Drawing 6 A is a master bond shrine (Master Bond, Inc.) of New Jersey and Hackensack (Hackensack) marketed with the trademark "Mastersyl 151". It is the graph of the temperature

pair Young's modulus about a silicon presentation. Drawing 6 B is the graph of the temperature pair Young's modulus of the same silicon ingredient with which it filled up with carbon black. The used carbon black bulking agent is the Canada country and Alberta (Alberta). A state, Mehdi Soon Can curve company of a hat (Medicine Hat) (Cancarb Limited) It was THERMAX Medium Thermal Black N -991 marketed. Glass transition of a silicon ingredient has placed the core per -66 degrees C that the hardness of an ingredient decreases detrimentally as temperature increases to about 370p.s.i. more than glass transition temperature so that drawing 6 A may see. A glass transition region is still nicer and this operation should be contrasted with the silicon ingredient with which it filled up with the carbon black of drawing 6 B which puts a core on -72 degrees C below gyroscope operating range. Since a bulking agent is heated more than glass transition temperature, that the Young's modulus of an ingredient is seen decreasing gradually arises. If it contrasts with the silicon ingredient lacking in a bulking agent, by the way, the sample of drawing 6 B is approaching the stable Young's modulus of the value of abbreviation 1,500p.s.i. in a field with elasticity. Thus, experimental data has proved the specific bulking agent, i.e., the effectiveness of carbon black, as what hardens a silicon ingredient when heated more than the glass transition temperature.

[0025] The artificer applied the desirable property of the observed silicon and a silicon restoration pot-ized ingredient to manufacture of a gyroscope sensor coil, and realized the remarkable result about the engine performance which improved. Drawing 7 is the graph of a bias error as a function of temperature about the gyroscope containing the sensor coil pot-ized by the silicon presentation hardened by the carbon black of drawing 6 B. Bias data were obtained from 40 layer-winding sensor coil formed with the 200-meter 165-micron optical fiber by Corning, Inc. The data of drawing 7 are amended about both a gyroscope output and the linear relation of temperature, and the rate dependence of temperature like [ in the case of the data plotted by drawing 3 and the graph of 4 ]. Becoming what has the standard deviation of 0.19 degrees per time amount, and the residual bias which remains can disregard as the temperature of a sensor coil circulates through for -50 degrees C and 95 degrees C is seen. Neither a bias spike nor bias crossing exists in the data of drawing 7 . If the data of drawing 7 , drawing 3 , and the data of 4 are contrasted, it will be dramatic and an artificer's penetration and assumption will be proved about the property of the problem relevant to pot-izing a sensor coil by the polymer.

[0026] Drawing 8 is the graph of AC bias by oscillation frequency pair sine wave vibration about the coil pot-ized with the silicon with which it filled up with carbon black. This bias data was similarly obtained from 40 layer-winding coil formed with the 200-meter 165-micron optical fiber by Corning, Inc. AC bias output can be substantially disregarded in this measurand as this graph shows. The vibration acceleration level was kept constant at 1g. Thus, it turns out that instruction of this invention offers the sensor coil substantially improved about minimization of the bias sensibility resulting from dynamic heat and an oscillating environment. By using instruction of this invention, the gyroscope engine performance which is not substantially exposed to the bias error of the environmental cause that recognition or a measure was not made before can be obtained with the conventional technique. Although this invention was explained about operation zero suitable at present, it does not restrict to it. Rather, this invention is restricted only in the limitation defined by the attendant claim, and contains all the equivalents of it within the limits of it.

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the perspective view of the sensor coil for optical fiber gyroscopes by this invention.
[Drawing 2] It is the expanded sectional view of the typical part of the coil used as the layer of the sensor coil by this invention.
[Drawing 3] NORLAND It is drawing of a graph about the gyroscope containing the sensor coil pot-ized with the UV hardening polyacrylate adhesive 65 showing the bias as a function of temperature.
[Drawing 4] NORLAND It is drawing of a graph about the gyroscope containing the sensor coil pot-ized with the UV hardening polyacrylate adhesive 65 showing the bias as a function of temperature.
[Drawing 5] NORLAND hardened as a function of temperature It is drawing of the graph of the Young's modulus of the polyacrylate adhesive 65.
[Drawing 6 A] It is the graphical representation of the Young's modulus of a silicon presentation in case the carbon black bulking agent as a function of temperature is not included.
[Drawing 6 B] It is the graphical representation of the Young's modulus of a silicon presentation in case the carbon black bulking agent as a function of temperature is included.
[Drawing 7] It is drawing of the graph of a bias error as a function of temperature about the gyroscope containing the sensor coil pot-ized by the silicon presentation containing a carbon black bulking agent.
[Drawing 8] It is drawing of the graph of AC bias by oscillation frequency pair vibration about the coil pot-ized with the silicon with which it filled up with carbon black.
[Description of Notations]
Optical fiber 12
Support spool 14
Adhesives 16